

the axes and in the azimuth of the major axis of the elliptically polarised light, and was observed in the case of two different crystals which were made the subject of experiment.

Since the light reflected from the surface of the crystal is exceedingly nearly plane polarised, the absolute value of the change in the ratio of the axes is small; but the relative change is considerable, for $\tan \varpi$ is altered by polishing from 0.0334 to 0.0252. Also the change in the azimuth of the major axis is not very large.

As regards the disturbing causes, it is found that temperature and time do not cause any very perceptible alterations in the surface state of a polished crystal.

The experiments prove a result unnoticed by Seebeck, that an emery-rouge polished surface gives perfectly concordant results on repolishing, and in this respect is quite as satisfactory as the chalk-polished surface recommended by him. This conclusion is supported both by the elliptic and simple analysers. And in general the results of the paper tend to confirm the views of Seebeck rather than those of Sir J. Conroy, for Seebeck in his paper prefers polished surfaces because of the liability of the natural surface to tarnish.

In conclusion, my best thanks are due to Mr. Glazebrook for his advice, and to Professor J. J. Thomson for placing at my disposal a room and apparatus in the Cavendish Laboratory.

“Further Experiments on the Distribution of Micro-organisms in Air (by Hesse’s Method).” By PERCY F. FRANKLAND, Ph.D., B.Sc., F.C.S., and T. G. HART, A.R.S.M. Communicated by Prof. FRANKLAND, D.C.L., F.R.S. Received November 22,—Read December 9, 1886.

[PLATE 3.]

In a previous communication entitled “The Distribution of Micro-organisms in Air,” a number of experiments have been recorded by one of us on the relative abundance of microbes in the air of various places and of the same place at different times. The numerical determination of the aerial micro-organisms in these experiments was made by means of Hesse’s apparatus, the method of using which was there fully described. Since the publication of the above experiments we have been extending our investigations by means of this method, and the results which we have obtained form the subject of the present communication.

In addition to the determination of the number of micro-organisms
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in a given volume of air by means of Hesse's process, we have also, as before, determined in each case the number of microbes falling on a given horizontal area in unit of time, by the exposure of small dishes containing sterile nutrient gelatine, as previously described.

During the hot weather we have experienced considerable difficulty in working with Hesse's tubes, which are very liable to melt in transport and when exposed to the sun; to obviate this we have made a practice on hot days of surrounding the outer surface of the tube with a coating of bibulous paper saturated with water, and this envelope was again covered with a coating of white tissue paper to prevent the former drying too rapidly. Owing to this precaution we have scarcely ever lost a tube even on the warmest days.

The greater number of our observations have been made on the roof of the Science Schools, South Kensington, which thus form a continuation of those already recorded. We have also made further experiments in Hyde Park, the Brompton Hospital for Consumption, the Natural History Museum, and in the garden of the latter closely adjoining the traffic in the Exhibition Road, South Kensington.

I. Roof of Science Schools, South Kensington.

The samples of air were here collected at a height of about 60 feet above the ground in the manner previously described. The particulars of the experiments are recorded in the following table (Table I).

These experiments, taken together with those already published, form a continuous series, excepting a few breaks, from January to the end of October of the present year, and serve to illustrate the changes which take place in the prevalence of aerial micro-organisms according to the seasons.

In order to render these results more readily intelligible, we have also expressed them by means of a curve in the accompanying diagram (Plate 3), in which the ordinates represent the number of micro-organisms found in 10 litres of air, whilst on the horizontal axis the dates are marked off. Below, on the same diagram, the temperature of the air at the time of experiment is recorded.

From this diagram it will be seen that, although the number of micro-organisms in the air frequently undergoes great changes from one day to another, yet the general tendency is for the number to follow the temperature. Thus, on taking the average of the results obtained in each month, the following sequence is arrived at:—

1886.	Average temperature at time of experiments.	Average number of colonies obtained from 10 litres of air by Hesse's method.
January....	3.5° C.	4
March.....	6.9	26
May..	13.4	31
June	20.2	54
July	23.6	63
August	18.3	105
September .	12.9	43
October....	12.5	35

From the above it will be seen that it is during the hottest months of the year—July and August—that the largest number of micro-organisms is present in the air. In September the number underwent a great reduction, which was further continued in October.

II. *Experiments in Interior of Buildings.*

In Table No. II we have recorded a number of experiments which we have made in the interior of buildings, viz., in the Hospital for Consumption, Brompton, in Burlington House, in the Natural History Museum, in the Chemical Laboratory of the Science Schools, South Kensington, as well as in a barn and cowhouse in the country.

The results of the above experiments fully substantiate the previous observations made by one of us, that in the interior of buildings, &c., the number of organisms present in the air is almost wholly dependent upon whether the latter is in a disturbed state or not, and that when undisturbed the number is generally considerably less than in the open air, whilst in crowded rooms the number rises enormously. Thus in the Hospital for Consumption, when only a few persons were moving about the ward, the air was remarkably free from microbes, the number increasing somewhat when the number of people in the room increased, but even then the number fell very far short of that in the crowded rooms of the Royal Society during the conversazione, or in the Natural History Museum on Whit Monday, whilst the greatest number which we have ever recorded was found in a barn in which the operation of thrashing was going on, the number of micro-organisms falling on the square foot in one minute amounting there to upwards of 8000.

III. *Miscellaneous Open-Air Experiments.*

In Table III we have recorded the results of some experiments

made in the open air at other places than the roof of the Science Schools. This table includes, in the first place, a comparison between the number of micro-organisms present in the air of Hyde Park, the roof of the Science Schools, and the entrance to the latter in the Exhibition Road respectively, the experiments in these three places being all made on the same day. It will be seen that the air in Hyde Park contained markedly less than either of the other two, and that the air in the Exhibition Road in which a large amount of traffic was going on at the time was considerably richer in micro-organisms than the air on the roof.

Then follow several experiments made in the garden of the Natural History Museum in the immediate vicinity of the Exhibition Road. In every case, excepting one, this air was exceedingly rich in micro-organisms, as was to be anticipated; whilst on the occasion when the number of organisms was small, the wind, which was very gentle, was not blowing from the road but over the grass of the garden which was damp at the time.

The above experiments are intended to form a supplement to those already published by one of us, in which the same method of investigation was pursued. In the course of these experiments we have found that the results obtained with Hesse's apparatus are liable to considerable inaccuracy when the latter is employed in a disturbed atmosphere, more especially when the aerial currents are irregular in direction. This source of error has been fully discussed in another paper by one of us, and a new method of examining air for micro-organisms, in which this difficulty is overcome, has been devised and its accuracy carefully tested.

[*Note*.—Since the communication of the above, we have completed the observations for November and December, with the following results:—

1886.		Average temperature at time of experiments.	Average number of colonies obtained from 10 litres of air by Hesse's method.	
November..	9·4° C.	13
December..	4·4	20

March 5, 1887.]

Table I.—Roof of Science Schools, South Kensington Museum.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>June 7th.</i> 4.15—5.15 P.M.	Wind N.E. by N., moderate but variable, and irregular in direction, blew into tube during the 11th litre. Sunshine, roads dry, except where watered. 21° C.	74 in 12 lits.	62	52
<i>June 18th.</i> 4.15—5.15 P.M.	Wind N. varying to N.W. and N.E., slight. No rain on previous day, but few drops during experiment. Roads dry, except where watered. 10° C.	12 in 12 lits.	10	85 (1) 82 (2)
<i>June 21st.</i> 5—6 P.M.	Wind W. by N.W., moderately strong but constant. Roads dry, except where watered. No considerable rain since night of June 18th. Cloudy. 14° C.	27 in 12 lits.	23	107 (1) 146 (2)
<i>June 22nd.</i> 3—4 P.M.	Wind W. by N.W., rather stronger than on previous day. Only small quantity of rain since previous day. Slight sunshine. 18.5° C.	53 in 12 lits.	44	153
<i>June 24th.</i> 4—5 P.M.	Wind W. by S.W., very strong and gusty. Much dust blowing about. No rain on previous day. 22° C.	135 in 12 lits.	113	1919 (1) 1714 (2)

Table I—*continued*.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>June 25th.</i> 3—4 P.M.	Wind W., <i>moderately strong</i> . Roads watered, but rather dry at the time. No rain on previous days. 23° C.	114 in 12 lits.	95	468
<i>June 26th.</i> 12—1 P.M.	Wind S. by S.W., <i>very gentle</i> . Hot and sultry. Roads watered previously. No recent rain. 25.5° C.	52 in 12 lits.	43	50
<i>June 28th.</i> 3.40—4.30 P.M.	Wind N.E. by E., <i>moderate but variable</i> . Roads watered. No rain. 21.5°.	49 in 12 lits.	41	133
Ditto. 4.40—5.25 P.M.	Wind <i>moderate and not quite so variable</i> as in previous experiment, increased <i>very</i> much at 5.12 P.M.	52 in 12 lits.	47	188
<i>June 29th.</i> 3—4 P.M.	Wind N.E., <i>very gentle</i> and fairly constant. Sunshine, <i>very hot</i> . No previous rain. 24° C.	45 in 12 lits.	38	56
<i>June 30th.</i> 4—5 P.M.	Wind N.E., <i>very considerable</i> , and increased <i>very</i> much at end of experiment. No previous rain. 21° C.	75 in 10 lits.	75	226

Table I—continued.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>July 2nd.</i> 4—5 P.M.	Wind E., <i>gentle</i> , increased somewhat during experiment. No previous rain. Sunshine throughout day. 24.7° C.	51 in 12 lits.	43	100
<i>July 3rd.</i> 12—1 P.M.	Wind N.W., but <i>almost perfectly calm</i> . Roads well watered, but no previous rain. Very hot and sultry. 26.1°	38 in 12 lits.	32	42
<i>July 5th.</i> 3—4 P.M.	Wind N.W., <i>considerable</i> . No previous rain, but roads well watered; some dust seen, however, to be blown about. 27.7° C.	121 in 12 lits.	101	283
<i>July 6th.</i> 3—4 P.M.	Wind N.W. by W., <i>very considerable</i> . No previous rain. 27.5° C.	78 in 12 lits.	65	364
<i>July 7th.</i> 1.30—2.30 P.M.	Wind S.W. by W., <i>very slight indeed</i> . No previous rain. 25.5° C.	55 in 12 lits.	46	226

Table I—continued.

Date, 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>July 8th.</i> 6—7 P.M.	Wind N.W., <i>moderate</i> . No previous rain. 22.2° C. The number of colonies in the tube is only approximate, owing to the growth of a large liquefying colony.	(33 in 12 lits.)	(28?)	273
<i>July 9th.</i> 3—4 P.M.	Wind N.E. by E., <i>strong</i> . No previous rain. 17.5° C.	59 in 12 lits.	49	143
<i>July 12th.</i> 12—1 P.M.	Wind S.W., <i>slight</i> . Considerable rain during preceding night. Roads, &c., quite wet during the morning, but drier at time of experiment. Slight rain during experiment. 21° C.	72 in 12 lits.	60	88
<i>July 21st.</i> 4.18—5.20 P.M.	Wind S.W., <i>very gentle</i> , but <i>increasing</i> considerably at end of experiment, when it changed to W. by N.W., and blew much dust about. 26° C.	129 in 12 lits.	108	203 (little wind) 798 (more wind)
<i>July 29th.</i> 12.40—1.45 P.M.	Wind S.W., <i>gentle</i> , but <i>variable</i> , both in strength and direction. No previous rain, but roads well watered. 22.5° C.	86 in 12 lits.	72	P.M. 180 (1) { 1.7 to 1.37 220 (2) { 1.80 to 1.45

Table I—continued.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>July 31st.</i> 12.15—1.5 P.M.	Wind W., <i>fairly strong, but varying in strength</i> . Rain during previous night, but roads and pavements quite dry; dust seen to be blowing about in road below. 18°-6° C.	108 in 12 lits.	90	252
<i>August 3rd.</i> 3.45—4.45 P.M.	Wind N.W., <i>gentle, but variable in direction</i> . Rain on the morning of previous day. Roads watered (the number of colonies obtained in the 10 litres is not reliable, and must be too low, as the aspirator leaked during a part of the time). 18°-3° C.	(105 in 10 lits.) ?	(105?)	126
<i>September 24th.</i> 3.30—4.20 P.M.	Wind N. by N.W., <i>very gentle</i> , but variable both in strength and direction. No rain for some time previously. Roads watered, pavement dry (result of tube experiment probably too low owing to slight leakage). 13°-3° C.	(71 in 12 lits.) ?	(59?)	183 { 3.45 to 4.15 P.M. 132 { 4.1 to 4.32 P.M.
<i>September 25th.</i> 6.20—7.15 P.M.	Wind S.W., <i>very gentle</i> . No previous rain, but a few drops felt at beginning of experiment. Roads watered, pavement dry. 12°-5° C.	32 in 12 lits.	27	68 74

Table I—continued.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>October 19th.</i> 4.58—5.32 P.M.	Wind S.E., <i>gentle</i> , constant in direction. Rain during morning; roads wet, roof and pavement nearly dry.	31 in 9 lits.	34	57
<i>October 20th.</i>	Wind W. by S.W., <i>gentle</i> , but increased during experiment. Roads wet, pavement dry. Rain during previous night. 12° 8° C.	26 in 10 lits.	26	30
<i>October 22nd.</i> 10.44—11.25 A.M.	Wind S.W., changing to W., <i>very gentle</i> , but variable. Roads wet; roof still wet in places from heavy dew. Foggy morning, which had cleared to sunshine. 9° 4° C.	18 in 11 lits.	16	6
<i>October 25th.</i> 10.44—11.26 A.M.	Wind E., <i>very strong and gusty</i> , but fairly constant in direction. Rain earlier in the morning. Roads wet, pavement dry, roof damp. 11° 3° C.	68 in 10 lits.	68	278
<i>October 29th.</i> 10.51—11.38 A.M.	Wind S.W., <i>gentle</i> , with occasional gusts, fairly constant in direction. Roads and pavement wet. Roof still damp from previous rain. 16° 3° C.	35 in 12 lits.	29	42

Table II.—Interior of Buildings.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>June 1st.</i> 12.30 P.M. 3.30 "	<i>Hospital for Consumption, Brompton</i> ("Richmond" Ward, 8 beds). Windows slightly open at top. 17° C. Ditto. More people moving about than in the morning. 18.5° C.	19 in 10 lits. 5 moulds 34 in 10 lits. 6 moulds	19 34	18 66
<i>June 9th.</i> 9.20 P.M. 10.5 "	<i>Burlington House</i> , Royal Society's Library during Conversation. 19.5° C. Ditto. Room more crowded. 22.0° C. <i>June 10th.</i> 10.15 A.M. Ditto. Only 3 persons in room, much dust had fallen on furniture, &c. 17° C.	163 in 5 lits. 11 moulds 216 in 5 lits. 14 moulds 65 in 5 lits. 32 moulds	326 432 130	240 318 109
<i>June 14th.</i> 4.53—5.40 P.M. 5.45—6.32 "	<i>Natural History Museum</i> , Central Hall. Very large number of visitors (Whit Monday) and draught from entrance doors. 15.5° C. Ditto. Ditto. 15.0° C.	280 in 10 lits. 8 moulds 267 in 10 lits. 5 moulds	280 267	1755 1568
<i>August 20th.</i> 6 P.M.	<i>Cowhouse</i> , near Hughenden, Bucks. 3 cows in stalls, milking going on, dish exposed 3 feet from ground.	No tube	..	282

Table II—continued.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>August 20th.</i> 10 A.M.	<i>Barn</i> , near Hughenden, Bucks. One man thrashing rye with flail, doors wide open, dish exposed 3 feet from ground.	No tube	..	8555
<i>October 15th.</i> 4.50—5.35 P.M.	<i>North Chemical Laboratory</i> , Science Schools, South Kensington. About 40 students had been working until half-an-hour previously. Almost empty at time of experiment. 16.9° C.	30 in 10 lits. 16 moulds	30	29
<i>October 16th.</i> 2.3—2.35 P.M.	<i>North Chemical Laboratory</i> . As it was Saturday, only 12 students had been working in the morning, and had left about 1 hour previously, the laboratory being quite empty. 16.9° C.	13 in 9 lits. 11 moulds	14	13
<i>October 27th.</i> 10.59—11.34 A.M.	<i>Private Laboratory</i> , Science Schools. Windows and door closed, 3 persons in room, but not moving about. 16.9° C.	32 in 10 lits. 14 moulds	32	9
<i>November 12th.</i> 3—4 P.M.	<i>Private Laboratory</i> , Science Schools. Windows and doors closed. 18.6° C.	9 in 11 lits. 6 moulds.	8	7

Table III.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>June 4th.</i> Noon. 1 P.M.	<i>Hyde Park.</i> Wind N.E., moderate. Sunshine dry. 12.5° C. Ditto. Wind increased in strength. 13.5° C.	— —	— —	37 78
<i>June 7th.</i> 12.45 P.M. 4.15—5.15 P.M. 6.30—7.15 P.M.	<i>Hyde Park.</i> Wind N.W., moderate, but irregular. Sunshine. Roads dry, grass damp. 18.5° C. <i>Roof of Science Schools</i> , South Kensington. Wind N.E. by N. Moderate, but variable in direction, blowing towards tube during 11th litre. Roads partially watered. 21° C. <i>Entrance to Science Schools</i> in Exhibition Road. Much traffic in street causing dust. 18° C.	22 in 12 lits. 7 moulds. 74 in 12 lits. 7 moulds. 113 in 12 lits. 27 moulds	18 62 94	16 52 945
<i>June 8th.</i> Noon. 4 P.M.	<i>Natural History Museum Garden</i> , adjoining Exhibition Road. Wind S. Roads dry. 19° C. Ditto. Number of people passing along road greater than in morning. 19° C.	— 665 in 12 lits. 239 moulds.	— 554	499 499

Table III—continued.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
June 8th. 5 P.M.	<i>Natural History Museum Garden</i> , adjoining Exhibition Road. Wind S. Number of people passing along road greater than in morning. 18° C.	261 in 8 lits. 5 moulds	309	1255
June 9th. 12 noon.	<i>Natural History Museum Garden</i> . Wind S., but not quite so strong as on previous day. Traffic in road less. 17.5° C.	158 in 12 lits. 17 moulds.	132	262
June 10th. 4—4.45 P.M.	<i>Natural History Museum Garden</i> . Wind N.W., very slight and gentle. Heavy rain during greater part of morning. Grass damp, roads wet, pavement dry. Wind blowing across grass and not from road. 15.5° C.	20 in 11 lits. 3 moulds	18	81
August 20th. 11 A.M.	<i>Hughenden</i> , Bucks. Naphill Common, covered with heather and fern. Sunshine. Wind very slight. No rain since previous day.	—	—	78 ($\frac{1}{2}$ moulds)
6.30 P.M.	Ditto. Garden, grass all round.	—	—	91 ($\frac{3}{4}$ moulds)

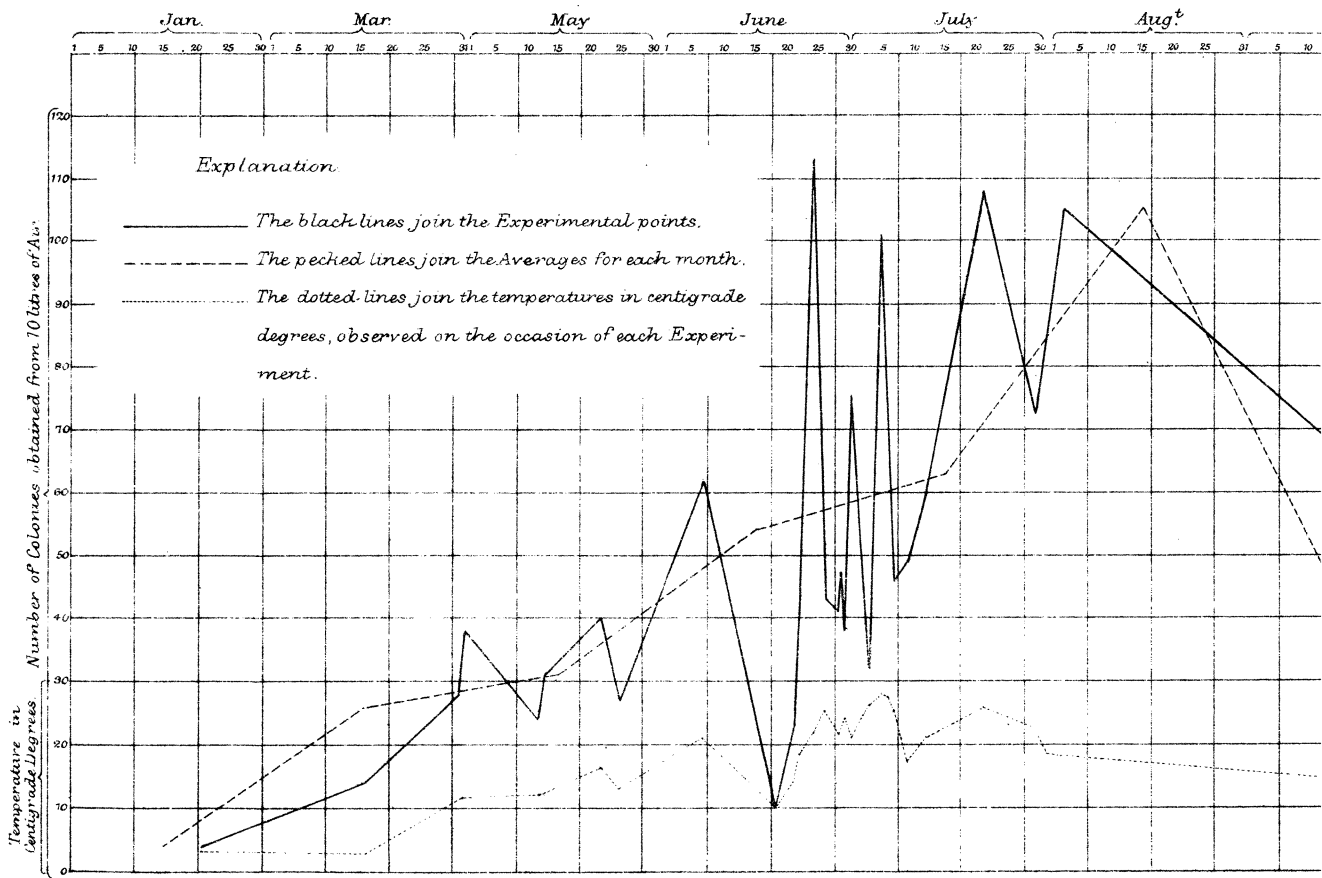
Table I—(Appendix. Added March 5, 1887.)

Date, 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
November 13th. 11 A.M.—12.30 P.M.	Wind W. by N.W., moderate, but rather variable in strength and direction. Four days' previous rain. Sunshine, roads wet, pavement dry. 6.9° C.	39 in 20 lits. 18 moulds.	20	88
November 20th. 11 A.M.	Wind S.W. by W., gentle, but variable in strength and direction. Roads and pavement still wet from rain on previous night. 12.5° C.	15 in 20 lits. 9 moulds.	8	43
November 26th. 2.45—3.35 P.M.	Wind E., moderately strong, but variable in strength and direction. Roads, &c., wet with dew. 8.6° C.	8 in 11 lits. 7 moulds.	7	17
November 29th. 2.45 P.M.	Wind S.W., very strong. Roads wet, pavement dry. 9.7° C.	21 in 12 lits. 8 moulds.	17	157
December 3rd. 3 P.M.	Wind W. by N.W., very gentle, but occasional gusts. Everything dry with hard frost. 0.8° C.	29 in 10 lits. 8 moulds.	29	125

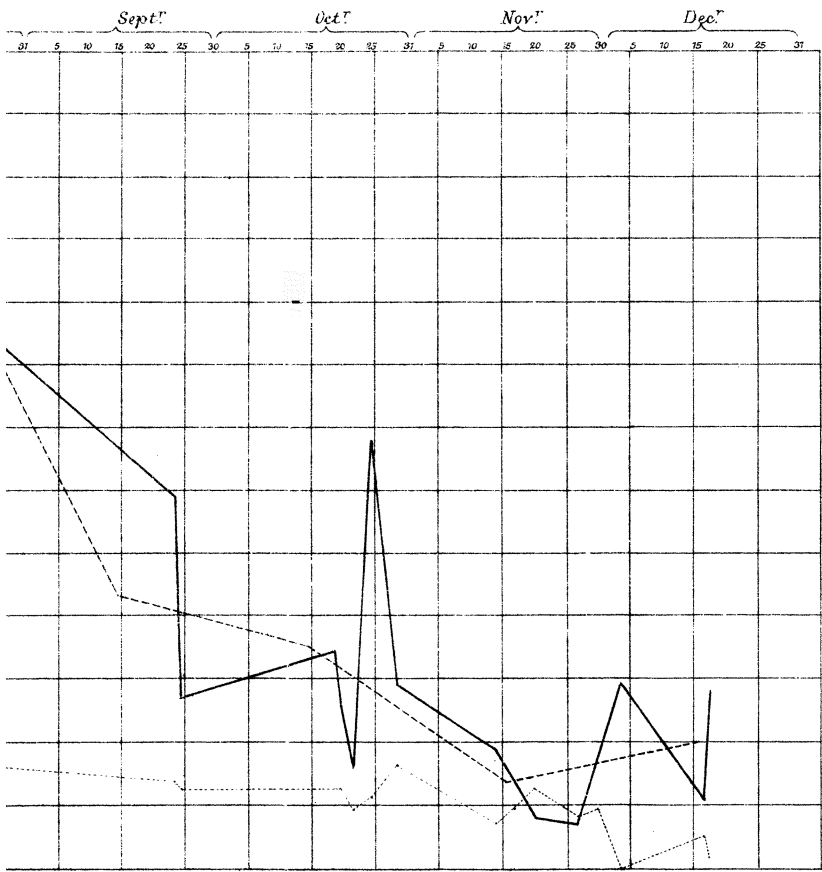
Table I (Appendix)—continued.

Date. 1886.	Conditions of experiment.	Number of colonies obtained from given volume of air.	Number of colonies from 10 litres of air (calculated).	Number of micro-organisms falling on 1 horizontal square foot per minute.
<i>December 16th.</i> 2—3 P.M.	Wind E. by N.E., gentle, but variable in strength and direction. Roads and pavement wet, very heavy rain two days before. 5.0° C.	15 in 13 lits. 4 moulds.	12	25 26
3—4 P.M.	Ditto. Wind slightly more gentle.	13 in 13 lits. 4 moulds.	10	39 31
<i>December 17th.</i> 1.20 P.M.	Wind E., gentle. Foggy. Roads, &c., wet. 2.5° C.	31 in 11 lits. 12 moulds.	28	74

100



ENSINGTON MUSEUM. 1886.



AIR collected on the Roof of SCIENCE SCHOOLS SOUTH KENSINGTON MUSEUM. 1886.

